

Numerical Studies of Rough Surface Scattering Models

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LONG-TERM GOALS

To develop a practical set of rough surface scattering strength equations for use in real-world Navy applications.

OBJECTIVES

To examine and develop theoretical surface scattering models that accurately predict acoustic wave scattering at the air-sea interface and at the ocean-bottom interface.

APPROACH

Two theoretical models for rough surface scattering, the small slope approximation (SSA) and the non-local small slope approximation (NLSSA), have been developed and examined. The former has been developed for scattering from the ocean bottom and the latter for scattering at the air-sea interface.

WORK COMPLETED

Work on the SSA using Biot theory was completed, and the NLSSA was further developed for scattering at low forward grazing angles.

RESULTS

The results of our work on the SSA using Biot theory are reported in a paper entitled “A comparison of perturbation theory and the small slope approximation for acoustic scattering from a rough interface for a Biot medium” which will appear in the July 2002 issue of *IEEE Journal of Oceanic Engineering* [1]. In this study, numerical results for perturbation theory (PT) and the SSA were presented and compared for both the backscattering and bistatic scattering strengths for a modified power law spectrum. Frequencies ranging from 100 Hz to 3 kHz were used for surfaces with *rms* heights h of 0.1 m and 1 m and a correlation length l of 10 m. For backscattering, the PT and SSA results agree for incident grazing angles up to approximately 45° for all surface parameters and frequencies considered (corresponding to $0.04 \leq k_w h \leq 12.57$ and $4.19 \leq k_w l \leq 125.66$ where k_w is the incident wavenumber). Thus, there is no advantage to using the SSA for low grazing angle backscatter. However, at high frequencies or for

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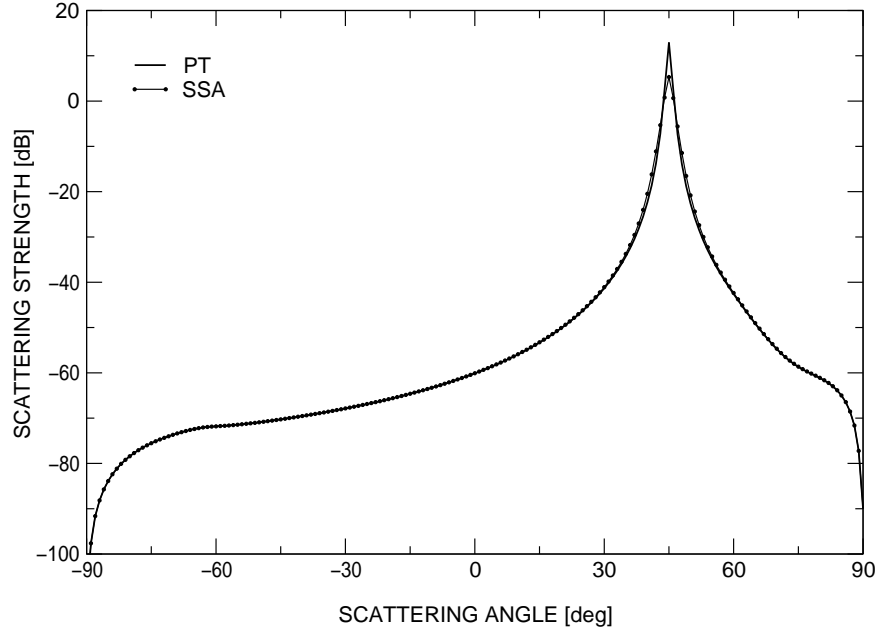


Figure 1: Bistatic scattering strengths as a function of scattering angle for lowest-order PT and SSA for $h = 0.1$ m, $l = 10$ m, $f = 3$ kHz, and an incident angle of 45° ($k_w h = 1.26$, $k_w l = 125.66$). The PT and SSA results agree over the entire range of scattering angles except in a very narrow angular region around the specular direction. This indicates that for this problem the PT results are accurate.

large scale roughness, the SSA may give more accurate results as the grazing angle is increased. For bistatic scatter, the PT and SSA results agree over all scattering angles for small roughness and at low frequencies as shown, for example, in Fig. 1. As the surface roughness or the frequency is increased, the results diverge, and in the specular region, the difference is considerable as shown in Fig. 2. While it is speculated that the SSA results are more accurate, exact results are needed for comparison for the accuracy to be determined. However, earlier studies indicate that when the SSA and PT results agree, the PT results are accurate.

The NLSSA was introduced by Voronovich as a generalization of the SSA to explicitly include non-local interactions [2]. Numerical results presented by Broschat and Thorsos showed that the NLSSA was accurate for conditions when the SSA was not [3]. However, the computational cost was prohibitive. An *ad hoc* approximation to the NLSSA cross section was made which reduced the computational complexity substantially while still giving good numerical results [4]. Most recently, additional approximations have been tried which further reduce the computational cost. The results are restricted to very low forward grazing angles, but this is a region of particular interest for modeling of rough surface scattering at the air-sea interface. A paper on this work is to be presented at the Acoustical Society of America meeting in Dec. 2002 [5].

IMPACT/APPLICATIONS

The development of approximate models that accurately predict wave scattering from rough surfaces is important in a number of Navy applications. For example, rough surface scattering models are needed in

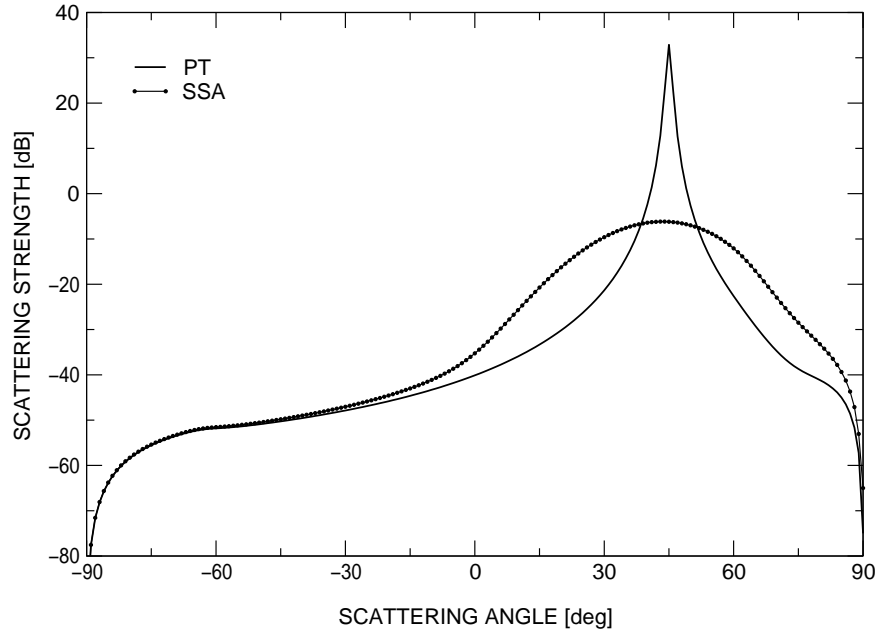


Figure 2: Bistatic scattering strengths for lowest-order PT and SSA for $h = 1$ m, $l = 10$ m, $f = 3$ kHz, and an incident angle of 45° ($k_w h = 12.57$, $k_w l = 125.66$). The increase in surface roughness height causes the PT and SSA results to differ markedly over a broad range of scattering angles. This indicates that PT is beyond its region of validity.

the simulations used by torpedo guidance and control personnel to test torpedoes. Another application for which rough surface scattering is critical is the detection of underwater mines, especially those buried in soft sediments. Other applications include ship wake detection, communications, and anti-submarine warfare. Of particular importance is that the models be as simple as possible while retaining the physical information necessary for the application.

TRANSITIONS

Much of the knowledge we have gained has been disseminated via publications and conference presentations. A search of the Science Citation Index online shows that previous ONR-sponsored work on rough surface scattering has been cited more than 150 times; it is believed that the current work will also be of use to others.

RELATED PROJECTS

This work is related to research in shallow water acoustics, high-frequency acoustics, and long-range propagation. The SSA Biot work is especially relevant to high-frequency, shallow water acoustics where the question of acoustic penetration into sediment is of much interest. The NLSSA work is relevant to long-range propagation since it attempts to model accurately scattering in the forward direction. Additionally, this work is related to that of several other ONR-sponsored researchers including Eric Thorsos and John Schneider.

REFERENCES

1. Yang, T.Q., S.L. Broschat, and C. Galea, "A comparison of perturbation theory and the small slope approximation for acoustic scattering from a rough interface for a Biot medium," to appear in *IEEE Journal of Oceanic Engineering*, Jul. 2002.
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5. Broschat, S.L., "Toward a practical cross section for rough surface scattering," 144th Meeting of the Acoustical Society of America, Cancun, Mexico, Dec. 2002.

PUBLICATIONS

1. Yang, T.Q., S.L. Broschat, and C. Galea, "A comparison of perturbation theory and the small slope approximation for acoustic scattering from a rough interface for a Biot medium," to appear in *IEEE Journal of Oceanic Engineering*, Jul. 2002.
2. Broschat, S.L., "Toward a practical cross section for rough surface scattering," 144th Meeting of the Acoustical Society of America, Cancun, Mexico, Dec. 2002.